Conference Paper

X-ray Diffraction Investigation of Sio_2/Si Track Templates with Deposited Zn

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Abstract

Si/SiO_2/Zn structures are fabricated by the track template synthesis. SEM and AFM images of the surface after electrochemical deposition of zinc were obtained. XRD analysis of the deposited samples showed the creation of zinc oxide nanocrystals with Miller indexes (200) at θ=62,3^0 and (201) at θ=69,5^0 (PDF#361451-etalon).

Received: 10 February 2018
Accepted: 14 April 2018
Published: 7 May 2018

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Selection and Peer-review under the responsibility of the RFYS Conference Committee.

1. Introduction

Currently, to create nanostructures in SiO_2, a combination of lithography and reactive etching is used. Swift heavy ion irradiation for formation of latent tracks in SiO_2 is of immediate interest today in connection with the fact that these tracks after treatment in some etching compositions can be transformed into nanochannel systems [1-3]. In comparison to the grooves etched in silicon dioxide using reactive ion etching, the sides of such kind of nanochannels are smoother. Because grooves formed by reactive ion etching do not always give smooth sides in connection with the use of aggressive gases, it leads to degradation of instrument characteristics. A possible solution could be the use of swift heavy ions radiation to create latent ion tracks in SiO_2. These tracks can be converted into nanochannels systems after the etching treatment in certain compositions. Such nanochannel walls are much smoother, when compared with grooves etched in the silicon dioxide with reactive ion etching.

At present the research for new (including alternative electronic) technologies for decreasing sizes of modern devices down to a nanometer scale is perspective. A promising and rapidly developing direction in this field is the structures containing nanodimensional heterogeneity as an alternative to standard lithographic techniques in micro- and nanoelectronics [4-7]. Amorphous silicon dioxide on silicon substrate can be used as matrix. After irradiation with swift heavy ions (SHI) and the subsequent etching in hydrofluoric acid solution, the system of nanochannels divided by dielectric layer is created [4]. The obtained template with the nanopores system can be used for creation of nanoclusters of semiconductors as well as for development an active elements of gas sensors and light emission diodes (LED), also another various electronic devices.

The purpose of the work is the research of ZnO nanoclusters in SiO_2/Si, obtained by the template synthesis method by XRD analysis.

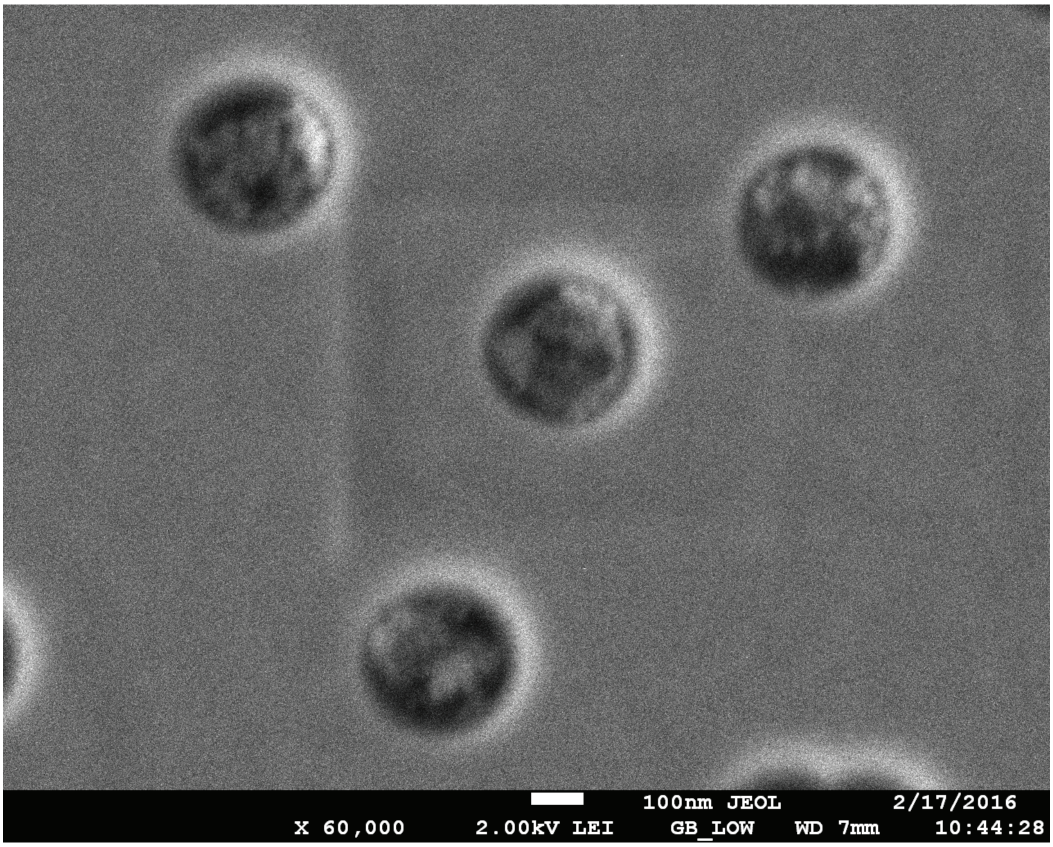


Figure 1: SEM image of SiO_2/Si surface, electrochemical deposition, 5 minutes, (Xe, 200 MeV, 1×10^9 cm^{-2}), JSM-7500F.

2. Experimental results and discussion

We have used SiO_2/Si structures of 1×1 cm size. SDB 12 (p-type silicon doped with boron) Si substrate with crystal lattice orientation (100), was subjected to wet oxygen oxidation at 900^0C in order to grow an oxide layer. The oxygen layer thickness, according to ellipsometry measurements, has been 600 nm.

DOI 10.18502/keg.v3i4.2223

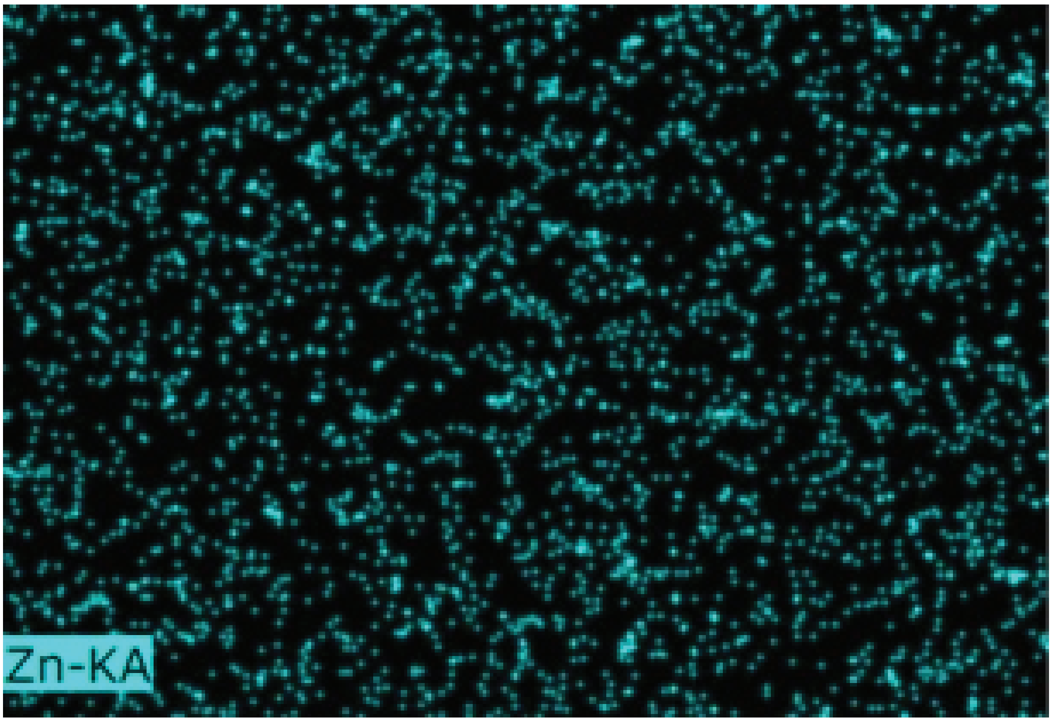


Figure 2: SEM image of Si/SiO$_2$/ZnO surface, (Xe, 200 MeV, 1×10^9 cm^{-2}), TM3030 .

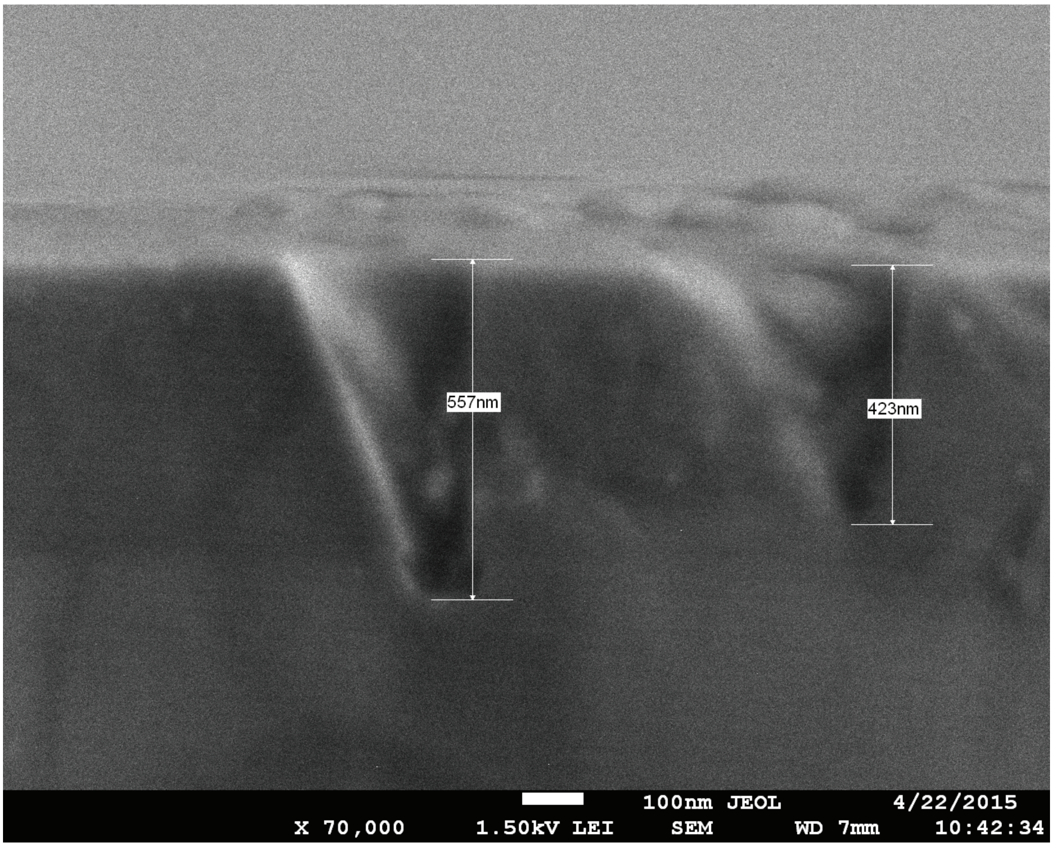


Figure 3: SEM image of the cross-section of Si/SiO$_2$/ZnO, electrochemical deposition (Xe, 200 MeV, 1×10^9 cm^{-2}), JSM-7500F .

The samples were irradiated on a DC-60 cyclotron (Astana, Republic of Kazakhstan) at normal beam incidence with 132 MeV and 200 MeV, ^{132}Xe ions under fluence Φ = 1×10^{9} cm^{-2}. To etch latent tracks, samples were treated in 4 % aqueous solution of hydrofluoric acid (HF) at room temperature for 7,5 minutes [4]. Sample have been cleaned in boiling (80^{0} C) C_3H_7OH (2 minutes), after in ultrasonic bathroom (15 minutes) and in deionized water (DIW) (18,2MOm). The template synthesis of zinc was carried out immediately after sensitization of surface and etching.The template synthesis (electrochemical deposition of metals) is universal and simple method of receiving arranged arrays of nanostructures in matrix channels [7].

Figures 1, 2 and 3 (scanning electronic microscope (SEM) images obtained by JSM-7500F and TM3030) demonstrate filling of nanopores with zinc by template synthesis method. Figure 2 demonstrate, that in case of chemical deposition there are sites from the deposited surface.

Treatment of irradiated samples with HF solution leads to formation of channels of conical shape with the diameters from ~84 to ~500 nm. It can be seen from Figure 3 that a nanopore holds the conical shape during electrochemical deposition.

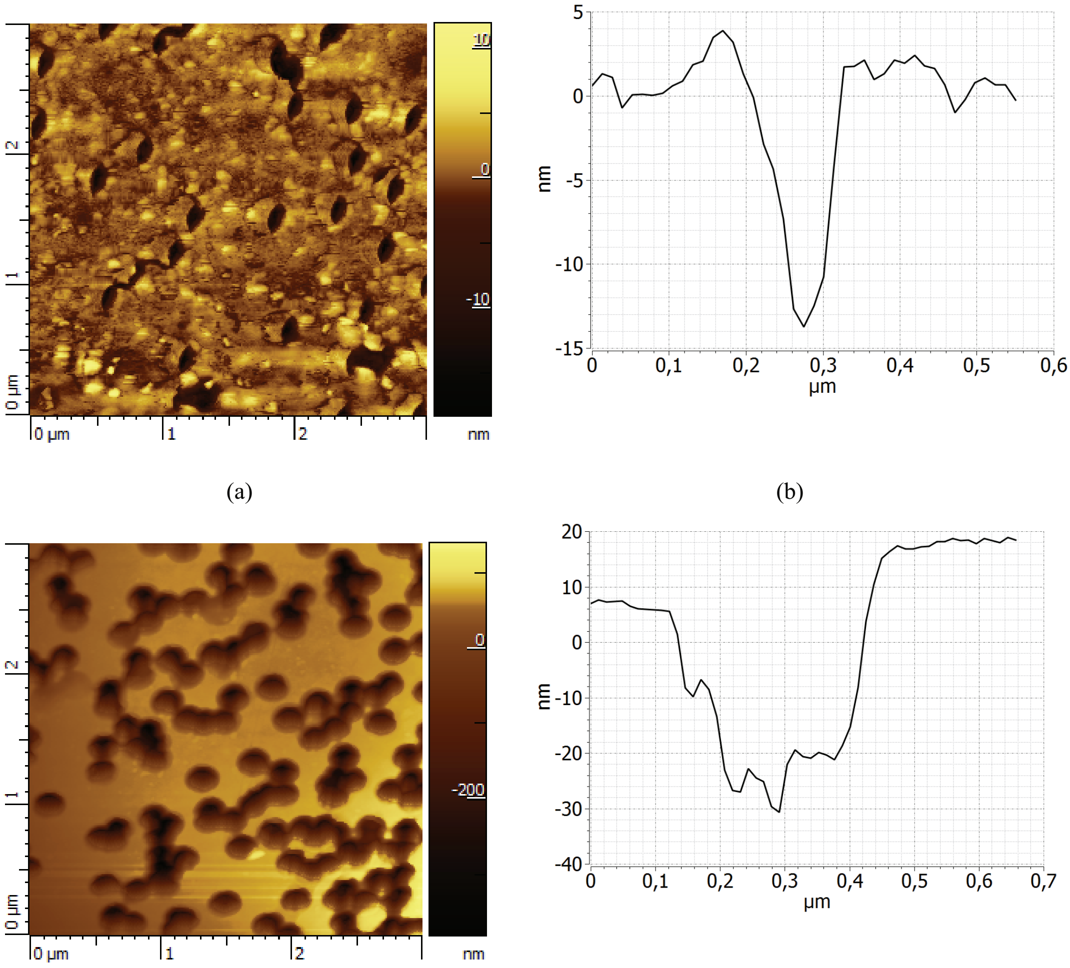
Figure 4 (a,b,c,d) shows surfaces and profiles (AFM image obtained by AIST-NT) of SiO_2/Si structure after etching the latent tracks (a, b) and after electrochemical deposition (c,d) of the structures of SiO_2/Si with Zn, (Xe 200 MeV, 1×10^{9} cm^{-2}).

How you can see at Figure 4 (d) profiles of SiO_2/Si structure after template synthesis are change, because nanopores of structure were filled by Zn.

By changing the time of electrochemical deposition it is possible to change sizes of deposited clusters. Figure 5 demonstrate the mass of Zn-clusters is grow up with increasing time of electrochemical deposition. Thus, the process of electrochemical deposition for structures of Si/SiO_2/ZnO is managed.

The X-ray diffraction analysis of the structures of SiO_2/Si was carried out in the x-ray diffract meter Shimadzu MAXima_X XRD-7000. The crystalline properties of the samples were studied by glancing angle incidence X-ray diffraction using Cu K α – radiation (λ=0,154 nm), operating at a voltage of 60kV and a current of 50 mA. The results are shown in table 1.

A X-ray diffraction patterns was recorded in the angular range 2θ=20-85^{0} with a step of 0,03° in the set of spectra for 3 seconds at each point. Analysis of the obtained diffraction patterns showed that the investigated structure is a zinc oxide nanostructure hexagonal primitive phase with Miller indices (200) at θ=62,3 ° and (201) at θ=69,5



(a) (b) (c) (d)

Figure 4: AFM images and profiles of SiO_2/Si: (a, b) before deposition (Xe, 200 MeV, $1{\times}10^9$ cm^{-2}); (c, d) electrochemical deposition (Xe, 200 MeV, $1{\times}10^9$ cm^{-2}) within 5 minutes.

Table 1: Parameters of elemental cell for ZnO.

	a	c	c/a	Size of Nanostructures
PDF#361451-etalon	3,249	5,206	1,602	-
Si/SiO_2/Zn	3,291	5,318	1,616	35,1±0,9

° (PDF#361451). Table 1 shows parameters of investigate nanostructure in comparison to the etalon.

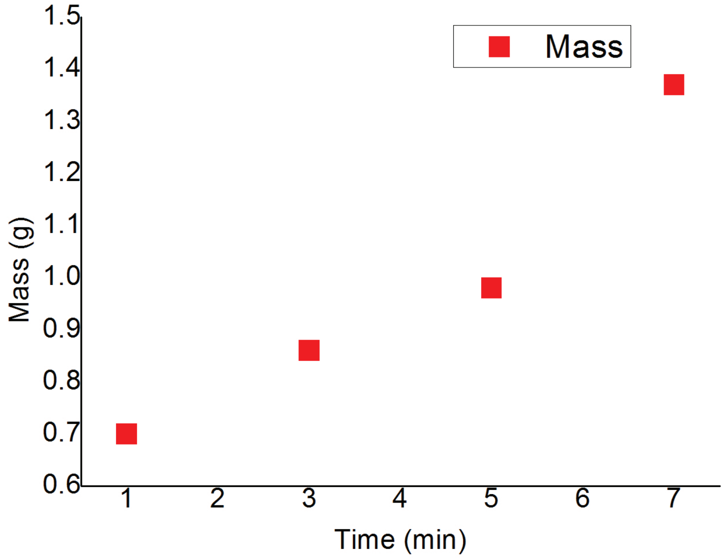


Figure 5: The dependency Zn clusters mass on the electrochemical deposition time (SiO_2/Si, Xe 200 MeV, $1{\times}10^9$ cm^{-2}).

3. Conclusion

Template synthesis (electrochemical and chemical deposition) leads to full filling SiO_2/Si nanochannels with zinc. The XRD patterns analysis enabled to assume creation of nanoclusters of zinc oxide in SiO_2/Si nanochannels. It was also established that these ZnO nanoclusters have the polycrystalline structure, hexagonal primitive phase with Miller indices (200) and (201).

References

[1] Dallanora A, Marcondes D, Bermudez T, Fichtner G, Trautmann C, Toulemonde M and Papaleo R 2008 *J. Appl. Phys.* **104** 024307

[2] Bergamini A, Bianconi M, Cristiani S, Gallerani L, Nubile A, Petrini S and Sugliani S 2008 *Nucl. Instr. Meth.* B **266** 2475

[3] Vlasukova L, Komarov F, Yuvchenko V, Mil'chanin O, Didyk A, Skuratov V and Kislitsyn S 2012 *Bulletin of the Russian Academy of Sciences. Phys.* **76** 582

[4] Al'zhanova A, Dauletbekova A, Komarov F, Vlasukova L, Yuvchenko V, Akilbekov A and Zdorovets 2016 *Nucl. Instr. and Meth.* B **374** 121

[5] Imry Y 1992 Nanostructures and Mesoscopic Systems **11** 32

[6] Shang H, Cao G 2007 *Springer Handbook of Nanotechnology* **161** 151

[7] Dauletbekova A, Alzhanova A, Akilbekov A, Mashentseva A, Zdorovets M and Balabekov K 2016 *AIP Conf. Proceedings* **1767** 020005-1